academicJournals

Vol.11(38), pp. 3710-3719, 22 September, 2016
DOI: 10.5897/AJAR2016.11267
Article Number: 5E730C160646
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Genetic diversity in sweet cassava from the Brazilian Middle North Region and selection of genotypes based on morpho-agronomical descriptors

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Received 29 May, 2016; Accepted 17 August, 2016

This work had as objective the morpho-agronomic characterization of germplasm of cassava (*Manhiot esculenta* Crantz) from the Brazilian Region Middle North and the selection of genotypes. The germplasm collection was carried out in autochthonous fields. 10 genotypes of which, 8 were ethno-varieties and 2 modern varieties (BRS Dourada and BRS Gema de Ovo), were collected. A completely randomized blocks design was used and the experiment was carried out in January of 2013 in Chapadinha-MA, Brazil. The morphological and agronomical characterizations were carried out at eight months after planting and at the harvesting time, respectively. The frequency of genotypes in each descriptor class and the entropy level for each descriptor were calculated. There was high phenotypic difference in the germplasm for most of the characters evaluated. Lowest entropy levels corresponded to the descriptors sinuosity of foliar lobe, margins of stipules, pubescence of apical bud, growing habit and color of stem epidermis. Highest entropy and consequently higher variability were noticed in petiole color, color of stem cortex, plant kind and peduncle presence. The genotypes Rampa and Turiaçu have higher productive and marketing value, thus are excellent alternatives for adoption and cultivation in the Middle North Region. The work proved to be a prominent approach in the screening and selection of promising and contrasting cassava genotypes. Cassava genetic resources occurring in the Brazilian Middle North Region represent a valuable resource in breeding programs of this crop.

Key words: Characterization, genotypes selection, *M. esculenta*.

INTRODUCTION

Cassava (*Manhiot esculenta* Crantz) is an important source of carbohydrate for over 700 million people worldwide, mainly in developing countries of tropical regions. This crop presents a wide genetic diversity (Lebot

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et al., 2015; Siqueira et al., 2009). Although cassava has been propagated mainly asexually since its domestication, it has kept its ability to reproduce sexually, therefore enhancing its genetic constitution (Elias et al., 2001). The genetic diversity of cassava germplasm results mainly from its reproductive characteristics, besides a significant anthropological contribution. All of these factors isolated or in association, have enabled this crop to maintain a wide genetic base.

Cassava genetic diversity is closely associated to its reproductive characteristics. This crop presents high cross-pollination (Ly et al., 2013), abrupt dehiscence of fruits (Souza et al., 2006) and high heterozygosis (Chavarriaga-Aguirre, et al., 1998; Duputié et al., 2007). Associated to these aspects, a fragile reproductive barriers of isolation between this crop and its wild congeners (Blaer et al., 2007; Bredeson et al., 2016; Nassar et al., 1995), allow the interspecific hybridization between cassava and wild species of *Manhiot* such as *Manihot glaziovii* (Nichols, 1947), *Manihot neusann* Nassar (Nassar et al., 1995), enhancing the genetic variability in this genus. In nature, there are diverse interspecific hybrids of cassava (Second et al., 1997). These individuals occur especially in the Brazilian biome "*Caatinga*'' place of higher occurrence of the species, consisting of valuable resources in the transference of desirable genes from wild to cultivated species.

Anthropological aspects have significantly altered the genetic makeup of cassava germplasm. This crop has been cultivated for more than 5000 years since its domestication in South America (Allen, 2002). Indigenous peoples have altered the species gene flow in the region since its domestication, by selecting and keeping desirable individuals from determined population. Nowadays, this crop is still the feeding basis for most of the remaining indigenous populations and traditional farmers in Brazil (Silva and Murrieta, 2014; Valle and Lorenzi, 2014). Intrinsic traits regarding this crop such as cultural aspects of peoples involved on its cultivation, as well as peculiarities on its agricultural management have enabled the keeping of high levels of genetic diversity into cassava genetic resources. These resources are mostly landraces and represent a diverse and valuable genetic resource for the species as a source of desirable genes in the genetic improvement of this crop.

Cassava germplasm found in the Brazilian Middle North Region represents genetic resources especially valuable for this crop. This region is known for an overlapping of biomes, which has a pronounced effect on the genetic resources occurring in it. These resources present considerable phenotypic plasticity and homeostasis, which makes them possess great adaptation ability (Moura, 2013). Additionally, cassava present remarkable resilience in terms of adaptation to poor soils conditions, a predominated condition of the Brazilian soils, especially in the Middle North Region. Even though cassava indexes of production in this region is still low, much lower than the Brazilian average (IBGE, 2010). The crop regional lower performance stems from the lack of proper varieties developed especially for the region as well as from the adoption of no-adopted cultivars. This points out for the need of a study program in the screening and development of more productive genotypes and incentive in the adoption of such cultivars in order to strengthen regional cassava production.

The characterization of plant germplasm based on morphological descriptors is a preliminary step in breeding programs (Rêgo et al., 2011; Upadhyaya et al., 2008), and it has a paramount importance in the genetic improvement of cassava (Fukuda et al., 2002). This tool provides accurate information about the germplasm, which increases the efficiency of its use and exchange, as well as in the determination of genetic diversity (Araújo et al., 2002). Additional advantages related to its application, consist of its lower cost compared to molecular characterization and ease of analysis.

The use of multicategoric data such as morphological descriptors allows a practical, economic and rapid assessment of the genetic variability in cassava germplasm. This tool is more suitable for regions with low levels of technology, allowing the economic assessment of polymorphism of plant germplasm. This tool should be associated with agronomical information, targeting the discrimination of accessions, particularly as to the attributes of economic importance. Morpho-agronomic descriptors has been widely used in the characterization of cassava and it is indispensable in the determination of strategies of on-farm conservation of germplasm, management of gene banks, selection of desirable genotypes and protection of cultivars (Elias et al., 2001; Mamba-Mbayi et al., 2014; Nick et al., 2008; Oliveira et al., 2015; Rimoldi et al., 2010). Despite its importance, the use of morpho-agronomic has been limited in the characterization of sweet cassava germplasm; therefore, the aim of this work was to study the morpho-agronomic characterization of sweet cassava germplasm from the Brazilian Middle North and the selection of genotypes for this region.

MATERIALS AND METHODS

Collection of germplasm

The collection of germplasm was conducted mainly toward autochthonous fields that have been kept by local families, which represent the most common model of cultivation of this crop in these states. 10 genotypes (Table 1), of which, eight were ethno-varieties that have been grown by traditional farmers were collected. The two checks (BRS Dourada and BRS Gema de Ovo), developed for the Brazilian Northeast Region by the Brazilian Enterprise of Agriculture and Research (Embrapa), where donated by one of the Embrapa Units (Embrapa Meio Norte) based in Teresina, PI.

The autochthonous varieties were collected in 5 different locations: in the Micro Regions of Medio Mearim, Chapadinha, São Luis, Itapecuru Mirim and Gurupi in Maranhão state and Bico do

Table 1. Germplasm of cassava collected in the Middle North Region of Brazil, Chapadinha-MA, 2013.

Code	Genotypes	Origin
56- MA	BRS Dourada	Embrapa-pi
57-MA	BRS Gema de Ovo	Embrapa-PI
58-MA	Orelha Leão	Middle Mearim-MA
59-MA	Gameleira	Middle Mearim-MA
60-MA	Pão	São Luís- MA
61-MA	Turiaçu	Gurupi- MA
62-MA	R-01	Chapadinha-MA
63-MA	Rampa	Itapecuru Mirim- MA
64-MA	Rosa	Chapadinha-MA
65-MA	Talo Vermelho	Bico do Papagaio-TO

Papagaio, in Tocantins State. The autochthonous varieties considered different by farmers, which characterized a fix sampling with a fix and directed model were collected in the fields (Hershey, 1992; Martins, 1994).

Establishment and layout of the experiment

The experiment was established in the January of 2013 in the beginning of the regional raining season, and was conducted in the community of Vila União, 3° 44´ 34''S 43° 21´ 07´´W, rural zone of the municipality of Chapadinha, MA. Brazil.

The climate of the region is Aw, with two well-defined dry and raining seasons (Köppen and Geiger, 1939). Chapadinha municipality has an altitude of 106.2 m, with respective annual means of 1,797 mm and 27°C for precipitation and temperature, respectively. The soil of the region is a yellow latosol with frank-sandy texture (Embrapa, 2006). The experiment was conducted in rain fed conditions and eventual irrigation was used just to compensate the unusual shortage of rainfall that occurred during the conduction of the experiment.

The experiment was arranged in a completely randomized design, with four replication and ten treatments. The experimental plots were constituted of simple rows, 5 m long, with spacing of 1.20 and 0.6 m between and within rows, respectively. Each row was had only one genotype, and 10 plants. Of the ten plants per row, the 6 central plants, totalizing 24 plants for each genotype were evaluated. Repeated evaluation within blocks and replication was performed in order to search for morphological variation within genotypes.

Selections of planting material, soil preparation, planting and fertilizer application were performed according to the recommendation of the cassava system of production for the region of Cerrado (Sousa and Fialho, 2008).

Characterization of germplasm

Characterization of germplasm was carried out at eight months after planting, at the recommended age for morphological characterization of cassava germplasm. The descriptors and the methodology used in the characterization were proposed by Fukuda et al. (2010). The genotypes were characterized by 24 morphological descriptors. For practical issue, the descriptors were dived into the following five categories: i) plant descriptor, ii) leaf descriptor, iii) stem descriptor and iv) tuberous root descriptor (Table 2).

In order to determine the germplasm genetic diversity, the percentage frequency of genotypes in each class of the descriptors and the entropy level for each descriptor was calculated. As shown below, the coefficient of entropy was calculated according to the Renyi coefficient of entropy (Renyi, 1960).

$$H = -\sum_{i=1}^{s} pi\, ln\, pi$$

Where: H= Entropy Coefficient; *Pi*= Frequency of genotypes in each class of descriptor.

The entropy measures the frequency of (n) access P = (p_1+ p_2+…p_n), where p_1 = fi/n e (p_1+ p_2+…p_n = 1) since n = (f_1+ f_2 +…f_n), where f_1+ f_2 and f_n are the counting of each descriptor class. The entropy for each descriptor changes according to the number of classes for each descriptor and the equilibrium of accessions frequency in the different phenotypic classes. Thus, the greater the numbers of phenotypical classes and the more balanced the proportion between the access frequencies in the different phenotypical classes, the higher the entropy for a given descriptor will be.

The agronomic characterization was performed at harvest, in the twelfth month after planting. For this, the genotypes were evaluated to mean productivity of tuberous roots; harvest index; number of roots per plant; Root length and diameter; plant height; height of first branching point; branching levels and length of phyllotaxis. The statistical analysis was performed with the help of the statistical software ASISTAT (Silva et al., 2009).

RESULTS AND DISCUSSION

The genotypes Rampa and Turiaçu presented the highest average yield of tuberous roots, which was significantly differentiated them from the others (Table 3). The average of the two genotypes is near the regional average (7400 kg ha^{-1}) and superior to the local cultivar (Rosa) (Table 3). The results demonstrate a good performance of these genotypes in the local conditions. The yield variation 1.56 and 6.08 $t.ha^{-1}$ was expected. This characteristic is controlled by a set of genes, besides being influenced by environmental factors, which justifies its high amplitude. It confirms the degree of difference between cassava germplasm found in the Brazilian Middle North Region and points out the importance of regional selection of genotypes. Although it is desirable to have high productivity in the cultivation of cassava varieties, the practice of early harvesting, inherent to the growing of sweet cassava, prevents the full expression of the productive potential of the genotypes.

A considerable variation (from 0.18 to 0.50%) for the harvest index (HI) among genotypes was observed. The highest average for this trait corresponded to the genotype Rampa, which shows its ability on a greater translocation of photo assimilation to tuberous roots. The HI varies depending on the ratio between the aerial part weight and root production, and purpose of cultivation. Low values for HI in cassava stem from an increased production of the aerial part of the plants at the expense of root production and are acceptable when the crop is

Table 2. Descriptors categories and their classes used in the morphological characterization of cassava germplasm, Chapadinha, MA, 2013.

S/N	Plant descriptors	Given categories
1	Branching habit	1-Erect; 2-Dichotomous; 3-Trichotomous and 4-Tetrachotomous.
2	Type of plant	1-Open; 2-Umbrella type and 3-Compact
	Leaf descriptors	
3	Apical leaf color	1- Light green; 2- Dark green; 3- Purplish-green and 4- Purple.
4	Pubescence of apical bud	1-Present and 2- Absente.
5	Petiole color	1-Yellowish-green; 2- Green; 3-Redish-green; 4- greenish-red; 5-red and 6-Purple
6	Developed leaf color	1-Light-green; 2-Dark-green; 3-Purplesh-green and 4-purple
7	Terminal branches color	1-Light-green; 2-Dark-green; 3-Purplesh-green and 4-purple
8	Leave´s rib color	1- Green; 2-Redish-green; and 3- Greenish-red
9	petiole position	1-Tilted up; 2-Horizontal; 3-Angled down and 4-Irregular
10	Prominence of leaf scars	1-Without prominence and 2-Proeminent.
	Stem Descriptors	
11	Color of stem cortex	1-Light yellow; 2-Light green; 3-Green and 4-Dark green.
12	Length of phyllotaxis	1-Short; 2-Middle and 3-Large.
13	External Color of steam	1-Orange; 2-Yllowish-green; 3-Golden; 4-Light brown; 5-Gray; 6- Silvery; 7- Gray; 8-Silvery; 9- Dark brown.
14	Color of stem epidermis	1- Cream; 2- Light brown; 3- Dark brown; 4- Yellow.
15	Growth habit of the stem	1-Straight and 2-Forked.
	Root descriptors	
16	Presence of peduncle in roots	1-Present and 2-Absent.
17	External color of roots	1-White; 2-Yellow; 3-Light brown; 4-Brown and 5-Dark brown.
18	Color of root Cortex	1-White; 2-Yellow and 3-Pinkish.
19	Texture of root epidermis	1-Smooth and 2-Rough.
20	Constriction of roots	1-Absent; 2-Little or none and 3-Average.
21	Root shape	1-Conical; 2-Cylinder and 3-Spindle.
22	Highlight pellicle from roots	1-Easy release and 2- Difficult release.
23	Highlight of roots cortex	1-Easy release and 2-Difficult release.
24	Position of roots	1-Horizontal and 2- Vertical tendency.

Table 3. Means of the production components of sweet cassava germplasm collected in the Brazilian Middle North Region, Chapadinha-MA, 2013.

Genotypes	P (tons ha^{-1})	HI (%)	NTRP (unit)	LR (cm)	RD (cm)	PH (m)	HFB (m)	LB (%)	FL (cm)
Rosa	2.962^{b}	0.271^{c}	7.291^{c}	26.2^{b}	42.532^{a}	199.0^{c}	84.0^{b}	71.5^{a}	19.507^{b}
Dourada	2.064^{b}	0.175^{c}	7.333^{c}	22.946^{b}	40.637^{a}	246.5^{b}	76.25^{b}	10.915^{c}	19.737^{b}
T alo Vermelho	2.643^{b}	0.253^{c}	8.541^{c}	25.278^{b}	35.521^{a}	169.75^{c}	94.0^{b}	79.247^{a}	13.36^{d}
Orelha de Leão	3.207^{b}	0.344^{b}	10.5^{b}	29.0^{a}	24.583^{a}	217.25^{c}	79.0^{b}	65.412^{a}	19.54^{b}
Rampa	6.086^{a}	0.539^{a}	11.0^{b}	27.166^{b}	40.666^{a}	217.0^{c}	101.25^{b}	82.565^{a}	13.845^{d}
Gameleira	1.912^{b}	0.347^{b}	7.375^{c}	29.833^{a}	35.104^{a}	209.75^{c}	142.5^{a}	68.727^{a}	21.867^{a}
R.01	3.686^{b}	0.371^{b}	6.937^{c}	28.983^{a}	48.806^{a}	211.5^{c}	58.75^{b}	38.375^{b}	15.452^{c}
Gema de Ovo	2.983^{b}	0.253^{c}	7.875^{c}	24.4^{b}	35.046^{a}	223.75^{c}	60.75^{b}	42.865^{b}	19.22^{b}
Turiaçu	5.85^{a}	0.42^{b}	14.208^{a}	32.108^{a}	44.641^{a}	289.0^{a}	145.25^{a}	70.442^{a}	21.212^{a}
Pão	1.561^{b}	0.185^{c}	5.925^{c}	23.403^{b}	39.287^{a}	203.25^{c}	65.5^{b}	76.62^{a}	20.927^{a}

Averages followed by the same letter in the column do not differ significantly at 5% level of significance. P-productivity, ton.ha^{-1}; HI-harvest index,%; NTRP- number of tuberous roots per plant; RL-root length, cm; RD- root diameter, cm; HP- plant height, cm; HFB- height of the first branching, cm; LB-level of branching,%; FL-length phyllotaxis, cm.

intended for animal feed. On the other hand, they are undesirable in the production of sweet cassava. Values above 60% for the HI are considered suitable in the production of this crop.

The highest average for the number of tuberous roots per plant (NTRP) corresponded to genotype Turiaçu. This characteristic is influenced by environmental conditions and by the pattern of carbohydrates allocation to the roots during the early stages of plant development. In this study, the genotypes with greater number of roots per plant (Turiaçu and Ramp) corresponded to higher yields (Table 3). Reduction on the number of tuberous roots per plant can occur with the increase in planting density.

The highest averages for root length (RL) corresponded to the genotypes Turiaçu, Gameleira, Orelha de Leão and R.01 (Table 3). This characteristic is an important component of production, which is used as a criterion by farmers in the adoption of sweet cassava varieties.

There was a high variation (from 169 to 289 cm) for plant height among the genotypes, and Turiaçu presented the highest average for this trait (Table 3). Studies on cassava show a positive and significant correlation between the above ground production and plant height. Although there is a positive interaction between plant height and production of tuberous roots, there is no definition of what are ideal heights of plants in cassava cultivation. Concerning the average height of the first branching (HFB), it was observed that the genotypes Turiaçu and Gameleira showed the highest average. As for the branch level, the lowest average corresponded to the genotype BRS Dourada.

Characteristics such as plant height, height of the first branching and branch levels, influence the conduction of cultural practices are crucial in the dynamics of photo assimilated allocation in cassava. Higher plants with greater height of the first branching facilitates cultivation and harvesting operation. Genotypes with lower plant height are more suitable for regions with the incidence of strong winds, where problems with plant toppling have to be overcome. The branching levels, on the other hand, determine the photo-assimilated dynamic of allocation in the plant, besides influencing the performance of cultural practices. As the branching level increases so does the competition for nutrient and water. Thus, the cultivation of more compact plants optimizes cassava cultivation, by allowing greater density in planting without affecting the allocation of photo-assimilate.

For phyllotaxis length (FL), the lowest average corresponded to genotype Talo Vermelho and Ramp, which significantly differed from other genotypes (Table 3). The length of phyllotaxis relates to the yield of propagating material. Plants with lower values for this trait have a higher number of buds per length of stem, being desirable in the optimization of use of the propagating material.

There was a high phenotypic difference between the germplasm for most of the characteristics relating to the descriptors of leaf (Table 4).

The difference in leaf descriptors of the genotypes was expected, considering this crop wide genetic diversity, the different levels of breeding of the genotypes, besides their cultivation in conditions different to those of their place of origin. Considering this, Albuquerque et al. (2009), points to the high environmental interaction of cassava, and this is capable of promoting pronounced phenotypic changes in this crop.

The descriptors sinuosity of leaf lobe, margin of stipules and pubescence of the apical bud presented the lowest entropy levels (Table 4). Smaller entropy for these descriptors occurs due to their small number of classes and the imbalance in the frequency of genotypes in each class of these descriptors. Additionally, the process of conscious or unconscious selection carried out by farmers on certain characteristics explains the predominance of these classes for a particular descriptor.

Characteristics such as the sinuosity of the leaf lobe have a close relationship with the photosynthetic process. According to Fukuda (2006), the smooth sinuosity of the leaf lobe increases the efficiency of this process by increasing the leaf area. Characteristic such as the absence of pubescence in the apical bud reflects genotypes higher level of breeding. Low entropy level for leaf sinuosity has been reported in previous studies in the characterization of cassava germplasm (Albuquerque et al., 2009; Vieira, 2009).

Medium values of entropy correspond to the descriptors position of petiole, and the colors of developed leaves, terminal branches and apical leaves (Table 4). For descriptors such as the color of developed leaf and terminal branches, there was a higher frequency of green (50%) and dark green (60%), respectively. There is a close relationship between the color of the terminal branches and the color of developed leaves. Since these last composes terminal branches, there are only slight differences between both as to color tone. Predominance of green color in developed leaves has been reported in the characterization of cassava germplasm (Albuquerque et al., 2009). In this work, it was observed that the four color categories of apical leaves proposed by Fukuda et al. (2010) and a higher frequency of light green color (Table 4).

Highest entropy values corresponded to petiole color and shape of leaf lobe (Table 4). A larger number of classes for these descriptors and the balance in the frequency of genotypes in these classes justify the high entropy values of these characteristics. Although they have no agronomic importance, the petiole color and shape of leaf lobe are fundamental to farmers in the differentiation of genotypes. These characteristics are additionally important in taxonomic characterization of cassava. High entropy for the shape of leaf lobe, confirms the high genetic diversity for this trait in cassava germplasm. High entropy for the shape of leaf lobe has

Table 4. Descriptors of leaf, their classes, frequency of genotypes in each class and the entropy level for each descriptor in the characterization of cassava germplasm from Brazil Middle North Region, Chapadinha, MA, 2013.

Leaf descriptors		Frequency (%)	Entropy level
Categories	**Classes**		
Petiole color	Reddish green	10	1.503
	Yellowish green	30	
	Red	30	
	Greenish red	20	
	Purple	10	
Petiole position	Horizontal	50	0.692
	Tilted up	50	
Shape of leaflet	Lanceolate shape	40	1.192
	Elliptical	10	
	oblong Lanceolate	10	
	Elliptical Lanceolate	40	
Sinuosity of foliar lobe	Smooth	100	0
Color of developed leaf	Green	50	0.942
	Dark green	40	
	Light green	10	
Color of terminal branches	Green	20	0.948
	Dark green	60	
	Light green	20	
Stipules margins	Entire	100	0
Color of apical leaves	Light green	60	0.948
	Purple	20	
	Purplish green	20	
Pubescence of apical bud	Absent	100	0

been reported in the characterization of cassava germplasm (Vieira, 2009).

There was phenotypic difference for most of stem descriptors (Table 5). Lower entropy levels corresponded to growth habit, phenotypic difference was not observed between the germplasm for this trait. The growth habit in cassava implies in the ease or difficulty of their cultivation. It is a characteristic of economic importance in the culture, which explains the selection on genotypes with ideal growth habit. A straight growth facilitates cultivation, resulting in more uniform areas of cultivation. In addition, it facilitates the harvesting and the marketing of propagative material.

Descriptors such as presence of latex, external color and color of the stem epidermis presented mean entropy values (Table 5). These characteristics have no economic importance, which explains a lower imbalance in the frequency of genotypes on the different classes of these descriptors. A higher frequency of the classes of light brown external color for the descriptors stem and color of stem epidermis as well as predominance of the colors yellow and light green for the color of stem cortex was observed. The color of stem cortex is a highly variable characteristic in cassava germplasm; however it is not agronomically important, which probably contributed to the no selection of specific colors over time. This characteristic is essential in the differentiation cultivars.

Higher entropies were observed for the descriptors color of stem cortex, branching habit and type of plant

Table 5. Descriptors of plant stem, their classes, frequency of genotypes in the classes and the entropy level for each descriptor in the characterization of cassava germplasm from Brazil Middle North Region, Chapadinha, MA, 2013.

Stem descriptors		Frequency (%)	Entropy level
Categories	**Classes**		
Growing habit	Upright	100	0
Branching habit	Dichotomic	20	1.028
	Erect	50	
	Trichotomic	30	
External color of stem	Light brown	50	0.942
	Gray	40	
	Silvery	10	
Color of stem epidermis	Light brown	70	0.800
	Yellow	10	
	Cream	20	
Color of stem cortex	Yellow	40	1.053
	Light green	40	
	Dark green	20	
Latex presence	Medium	50	0.692
	Few	50	
Plant kind	Compact	40	1.053
	Cylindrical	40	
	Open	20	

(Table 5). There was a predominance of erect branching habit (50%), compact class (40%) and cylindrical (40%) for the descriptors branching habit and type of plant, respectively. Characteristics like growth habit and type of plant determine plant structure, being determinants components of leaf area. Agriculturally, these characteristics affect the cultivation of cassava, increasing or decreasing the difficulty of harvesting. Characteristics such as erect branching habit of stem and compact plants were not prevalent in most studies of morphological characterization of cassava (Gusmão and Neto, 2008; Nick et al., 2008).

There was variability for all the descriptors of the tuberous roots (Table 6). The lower levels of entropy corresponded to the descriptors epidermis texture, pulp color and constriction of roots. It a predominance of the classes white and few o absent for the descriptors pulp color and root constriction were observed, respectively. The color of pulp in roots has been one of the most important features in the selection of genotypes of sweet cassava varieties, which explains the lower number of classes and the occurrence of specific classes for this descriptor.

Consideration as to the color of pulp is essential for the adoption of cassava varieties, wherein the preference for varieties with specific color of pulp varies according to the purpose of cultivation and region of production. In Brazil Midwest Region there is a preference for roots of yellow pulp (Vieira, 2009), while there is a greater preference for white pulp varieties in the North and Northeast regions of the country. Varieties of cassava presenting roots with yellow pulp are good sources of β-carotene. These varieties have been strategically incorporated into the diet in areas where nutritional deficiency rates are of concern (Welsh and Graham, 2002), and its adoption can contribute to food security of populations in these regions. A reduced amount of roots constrictions facilitates the processing of roots, especially when this is done manually. On the other hand, the epidermis texture has an aesthetic importance in the marketing of fresh roots.

Descriptors with mean entropy values corresponded to root position, external color and peeling. There was a predominance of the classes' vertical trend and light brown color for the descriptors position of roots and roots color, respectively (Table 6). Regarding the peeling of

Table 6. Descriptors of tuberous roots, their classes, frequency of genotypes in each class and the entropy level for each descriptor in the characterization of cassava germplasm from Brazil Middle North Region, Chapadinha, MA, 2013.

Tuberous root descriptors		Frequency (%)	Entropy level
Categories	**Classes**		
Format	Cylindrical	40	0.942
	Cylindrical-conical	50	
	Irregular	10	
Root position	Horizontal tendency	40	0.672
	Vertical tendency	60	
Epidermis texture	Rough	90	0.324
	Smooth	10	
External color	Dark brown	10	0.8
	Light brown	70	
	Whit or cream	20	
Cortex color	Pinkish	20	1.028
	White or cream	50	
	Purple	30	
Pulp color	White	80	0.499
	Cream	20	
Root constriction	Few or absent	80	0.499
	Medium	20	
Peduncle presence	Sessile	40	1.053
	Mixed	40	
	Pedunculated	20	
Pealing	Easy	50	0.692
	Difficult	50	

roots, there was a balance in the distribution of genotypes to the classes' easy and difficult peeling. This descriptor is greatly influenced by environmental conditions and has a great agronomic importance. Thus, it can be assumed that the prevalence of these classes for this descriptor in cultivated germplasm of cassava results from intensive selection over this crop. Descriptors such as the position, constriction and peeling of roots determine the efficiency of harvesting and processing of roots. Genotypes whose roots arrange predominantly horizontally in the soil make harvest easier because they require less effort in the uprooting of roots. Plants with horizontal roots tend to result in lower losses related to the remaining roots on the soil, compared to genotypes with roots with vertical arrangement. Smaller amounts of constriction in the roots and an easier peeling increase the processing efficiency of roots and the quality of the final product. These characteristics are even more important in traditional cultivation of cassava, where much of the processing is carried out manually.

Higher entropy corresponded to the descriptors presence of peduncle, cortex color and shape. Of these, only the shape of roots has economic importance. All these descriptors showed higher numbers of classes as well as a more balanced frequency of genotypes on these classes, suggesting greater difficulty in the selection of genotypes with specific classes for these descriptors. In addition to the high genetic variability, these descriptors are greatly affected by soil and weather conditions. There was a predominance of the classes conical-cylindrical, light brown and white or cream for the descriptors format of roots, external color and color of the roots cortex, respectively. There was also a predominance of the sessile and mixed classes for root peduncle. The shape of roots is fundamentally important in the marketing of sweet cassava, being preferred the cylindrical and conical-cylindrical shapes. The presence of peduncle facilitates the harvesting process (Albuquerque et al., 2009). The peduncle works as a natural barrier of protection to the roots, protecting them from oxidative processes and against pathogens. Thus, its presence reduces the ongoing problem of roots oxidation and exposure to pathogens, decreasing the rotting of roots and enhancing their shelf in post-harvest.

Conclusions

The genotypes Rampa and Turiaçu were the most promising as the production and consumption aspects are excellent alternatives for cultivation in the Brazilian Middle North Region. The Genotypes Rosa, R.01 and Rampa had the lowest plant heights, which allow easer cultivation and harvest. The genotype Rampa had the highest harvest index showing its high productive potential. The study showed a high genetic diversity of cassava germplasm in the Brazilian Middle North Region. The work proved to be an excellent approach in the screening and selection of promising and contrasting genotypes of cassava. Genetic resources of cassava that occur in the Brazilian Middle North Region represent a valuable asset for the breeding programs of this crop.

Conflict of Interests

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

This research was supported by the Foundation of Support to Research and Scientific Development of Maranhão (Fundação de Amparo à Pesquisa e Desenvolvimento Científico e Tecnológico do Estado do Maranhão- FAPEMA). The support was granted to the first author as an extension/research scholarship under the grant AEXT-04127/10.

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